14th Annual International Conference on Industrial Engineering and Operations Management Dubai United Arab Emirates (UAE), February 12-14, 2024

Publisher: IEOM Society International, USA DOI: 10.46254/AN14.20240498
Published: February 12, 2024

Improving Warehouse Capacity Utilization using Discrete Event Simulation Modelling

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Abstract

Improving productivity has been a key priority in the warehouse industry to meet the target demand. One of the most important factors influencing productivity is space utilization. This research analysis is carried out to determine the warehouse capacity utilization rate and its long-term viability. This study employs the Symptom Versus Problems Theory (SVP), mathematical computation, and related simulation. Many studies project that space utilization is the root cause of the entire network problem for the case company's warehouse that was selected for this study. The scenario was further estimated using a Frazelle Model, combined with discrete event simulation. A new layout design was built and displayed, including the key activities and operational areas with better space utilization and process throughput.

Keywords
Symptom Versus Problem (SVP), Frazelle Model, Discrete Event Simulation, Warehouse, Capacity Utilization.

1. Introduction

Logistics is an important element of daily operations. The ability of the organization to competently manage logistical operations can decrease unnecessary energy consumption, operational expenses, and improve productivity. An organization must designate appropriate resources to create warehouse operations that necessitates optimal space utilization for proper storage and material handling (Kusrini, Novendri, & Helia, 2018). Ranging from 40,000 sqft to 500,000 sqft, at startup majority of the warehouse area is often wide and spacious in order to accomodate workstations and inventory. But then, the space is seemed to diminished on its own after years of operating. study by (Karim, Abdul Rahman, & Syed Johari Shah, 2018) shows that the top 3 reasons of warehouse failure factors are labor productivity, warehouse space utilization, and inventory space utilization (Karim et al., 2018). This indeed show that under the banner of space insufficiency, warehouse daily operations may be affected when workers have limited amount of working area as their movement to conduct the activities are limited(Wang & Hua, 2019). Furthermore when the space are not properly utilized, managers may found it hard to store their companies inventory when on paper, there are actually more space to occupied but physically the warehouse are packed and full with boxes of inventory which lead to usage of external parties such as warehouse rental & container. These events will increase the cost beared by the company. To prevent this event from happening, warehouse optimization process must be executed. A study was conducted by (Caridade, Pereira, Pinto Ferreira, & Silva, 2017) in optimization of warehouse aspects by using Warehouse Management Systems (WMS). WMS is a very recommended tool in enhancing warehouse efficiency since the all the informations are being control over by the warehouse personnel. The study showed the redesign of the layout are based on the data of product amount and the frequentness of picking based on the information provide by WMS. On the other hand, the cost and time taken for implementing doesn’t favour the the business goals which contemplating with cost reduction and

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fast improvement lead time (Herghiligiu et al., 2019). Therefore, business owners do need substantial amount of resource to adapt this systems. Thus, this paper first aim is to find the (Herghiligiu et al., 2019) root cause of current warehouse productivity and to investigate on what would be the ideal warehouse space capacity utilization.

(Torabizadeh, Yusof, Ma'aram, & Shaharoun, 2019) study shows that in the past 10 years there has been a pressure for a company to focus on the performance of the sustainability more than the financial aspects. Based on ISO 14000 environmental management systems (EMS) guideline, an organization should make an effort to contribute to the environment. However, based on the Environmental Performance Index (EMP) of 2018 (EPI Results, 2018), Malaysia rank in 75th from 180 countries across the world which shows that the awareness of environmental friendly is low in Malaysia. To promote sustainability, the design of the warehouse may have been one of the vessel for the company to comply such as the material used, recycled packaging uses and lighting systems used. Even though many parties perceives this as the profit barriers, there are certain data shows that it proofs to support business performances. Previous study shows the important of showcasing sustainability in economic, environment & social factor (Torabizadeh et al., 2019). In spite of this, this study doesn't provide the detail example of the sustainability features in terms of those aspects. Therefore, this paper will propose sustainable warehouse model

1.1 Case Company

The chosen company for this study is Bosch Rexroth Sdn Bhd located in Shah Alam, Selangor. Rexroth is one of the major subsidiaries in Bosch Group, majored in hydraulics and factory automation products (FA). Established in Malaysia in year 2001, Bosch Rexroth Shah Alam operates as sales & services entities, coupled with another branch in Penang. With a total of 71 employees till date, this company has a total of 30 different suppliers across the globe. Mainly are coming from its original Rexroth plant, there are some which are not entitled with bosch but being chosen as the 3rd party supplier, in order to fullfil the customer demand, just in case of any delay shipping and other unwanted scenario. Rexroth Shah Alam also has a local supplier which they are appointed as the backup supplier, as the lead time for the customer coming from overseas usually take 20 days by sea fright and 7- 12 days by air freight. Rexroth registered logistics courier and forwarder are mostly from established company such as DHL, Kuehne & Nagel and Panalpina. These are the parties responsible in helping Rexroth keep on operating on its daily basis. The products of Rexroth Shah Alam in hydraulics department are the cranes gearbox, valve, piston and modular pressure. For the FA side, there are assembling technology, linear motion technology & electric drives control. These informations are collected from the websites and during the interview sessions with the warehouse personnels and logistics manager.

1.2 Problem Definition

This company has performed well in terms of its sales for the past 2 years. Whereas on the other side, daily operations activities in the warehouse has been lagging and affecting the company performance. It is disiputed that, the productivity of the warehouse operations suffered a drop in the lead time operations. In addition, the environment of the workplace are not properly sort and managed due to several reasons. These unfortunate incidents prove to be one of the major problems suffered by this company. Workers are sightening on the lacked of space due to flooded inventory of high demand from the customers. They are working hard in order picking activities, but the rate seems to falling down due to unknown reasons.

Table 1. Worker Cycle Time Data

Worker 1 Month – September					
Process Name	Receiving	Open Shipment	Pick & Pack process	Charge Out from SAP	Prepare outbound shipment
Average time taken for each process (m)	10	15	35	5	10
Month – October					
Average time taken for each process (m)	15	20	50	10	15
Month – November					
Average time taken for each process (m)	20	30	75	15	15

As showin in Table 1. Average time taken of warehouse activities of worker 1 for the month of September, October & November of 2019. Based on Table 1, there are a total of 5 major activities that'll effect the productivity of warehouse operations. The first activity is receiving. Receiving is the process where inbound shipment carry by the company's designated forwarders. Warehouse personnel require to unload the pallet box from the truck and signed the official documents. This process will lagged on when a limited amount of space available to place the boxes into the warehouse area. Next, open shipment is an activity where store personnel need to unbox the goods and check whether the quantity and type of product is correct according to the purchase order documents provide by the office people. After all goods are checked accordingly, they will be updated on the SAP systems and the physical stock is then place on the pallet rack area. This process will required a lot of time if there are no spaces to place the inventory which lead to the worker initiative to rearrange the stock to make space for the new-coming stock. Third acitivity is pick and pack process where warehouse personnel pick the goods based on the picking slip generated. The interruption in this process may be caused by the unpresence the physical inventory or the items are misplaced at other location from the SAP systems. Another reason can be the items are placed at the back end or deep down from the pile of pallet rack on the floor. The charge out process is when all the require item are available to ship out, and the quantity being deducted in the SAP systems. Finally the order shipment is the process of loading the goods into the companies lorry and ready to be shipped to the customers. As stated, the average lead time of each process is increasing every month. This problem decrease the warehouse productivity significantly as the number of lead time decreased, the more the number of order may completed.

To help understand the vast network of warehouse productivity & sustainability, this paper attempts to answer and fullfill the following research questions:
Q1. What is the root cause of current warehouse low productivity ?
Q2. What would be the ideal warehouse space utlization in the company ?
Q3. What will be the proposed model of a sustainable warehouse ?

The remaining of this paper is organized as followed. The procedural steps of applying the methods are being explain after reviewing the literature. The result section will tabulate the findings in the shape of figures for the SVP analysis and equations for the mathematical computation. Following that, the next section discusses the findings, implications and suggestions for the company to choose in accommodating the best scenario for its warehouse. The last section discusses conclusions whether the research objectives are being achieves.

2. Warehouse Storage

Storage design allocation is the most crucial component that affect the performance of order picking and receiving. Many factors impact the location of products in the warehouse. For example, order picking method, size and layout of the storage system, material handling system, product characteristics, demand trends, turnover rates and space

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requirements. Choosing a proper storage assignment policy helps to improve the performance of order picking. The storage assignment policies that assign items to storage locations are usually random storage, dedicated storage and class-based storage categories. (Fumi, Scarabotti, & Schiraldi, 2013). The advantage of this policy is that fast-moving products can be stored near the warehouse, whereas flexibility and high storage space use of random storage are applicable. Frequently, there are two kinds of class-based storage, dedicated purposes and ABC classification (Sooksaksun, Kachitvichyanukul, & Gong, 2012). On the other hand, in the picker-to-part method, storage assignment is primarily divided into two categories that are the goods and customer orders. For products, (Fumi et al., 2013) pointed out that class-based storage depending on the product characteristics, the picking accuracy can be increased and order recovery time can be reduced. They emphasized that order recovery time and travel distance should be viewed by people as two different performance metrics for order picking. However, their research did not further investigate into the relationship between order retrieval time and distance travelled. On the other hand, (Cho & Ahn, 2019) proves that class-based storage by product turnover can improve accessibility for pickers of fast-moving items.

2.2 Warehouse Performance Measurement

A performance measurement system is a set of metrics used to calculate the efficiency and effectiveness of actions (Kusrini et al., 2018). Even though warehouse performance can be measured in to hard metric (costs, order cycle time and fill rates) and soft metric in general, efficiency and effectiveness are the most widely utilized as a measure of performance (Kusrini et al., 2018). It has been explored in a lot of ways by the researchers. These works differ from one another with respect to the objectives long- or short-term decisions, the way to measure these objectives (variety of performance indicators), the type of warehouse systems (distribution centre, cross-dock platforms, etc.), the focus area inside the warehouse (storage, picking, etc.) and the tools used for measurement (statistical tools, mathematical programming, etc.) . Warehouse manager needs to choose which type of suitable measurement with their warehouse environment. This is not an easy job since all the measurement are different (Gu, Goetschalckx, & McGinnis, 2010). Warehouses could have different activities according to product specification, customer requirements and service levels offered. According to (Frazelle, 2016), warehouse activities are divided into 5 activity, i.e.: receiving, put away, storage, order picking and shipping. Each activity can be measured by using 5 Key Performance Indicator (KPI), namely financial, productivity, utility, quality and cycle time. Therefore, there are 25 KPIs for measuring warehouse as depicted in Table 2 below.

Table 2. Key Performance indicator of Frazelle Model (Frazelle, 2016)

	Financial	Productivity	Utilization	Quality	Cycle Time
Receiving	Receiving cost per line	Receipts per man hour	% Dock door utilization	% Receipts processed accurately	Receipts processing time per receipts
Put away	Put away cost per line	Put away per man-hour	% Utilization of put away labour and equipment	% Perfect put away	Put away cycle time (per put away)
Storage	Storage space cost per item	Inventory per square foot	% Locations and cube occupied	% Locations without inventory discrepancies	Inventory days on hand
Order Picking	Picking cost per order line	Order line picked per man-hour	% Utilization of picking labour and equipment	% Perfect picking lines	Order picking cycle time (per order)
Shipping	Shipping cost per customer order	Orders prepared for shipment per man hour	% Utilization of shipping docks	% Perfect shipments	Warehouse order cycle time

2.3 Sustainability

Athough it is feasible for businesses, not much thought has been given to environmental and social aspects (Foroozesh, Tavakkoli-Moghaddam, & Mousavi, 2018). The proposed indicators by (Gutierrez, 2015) and (Ribino, 2018) are also focusing on economic and efficiency aspect while the social and environmental aspects are missing. In spite the Council of Supply Chain Management Profession: State of Logistics Report 2013 stated that researchers have paying attention to the sustainable supply chain and the green supply chain, the government indicated that, contrary to the growing int The importance of integrating sustainability in warehouse operations was discussed (Bintang, Nurcahyo, & Gabriel, 2019). They believed that companies involved in warehousing services must recognize the need for their businesses to consider sustainability issues. Because sustainability can help businesses to preserve their environment and protect human rights, as well as social responsibility (Sari & Kamalia, 2019) . Measurement of sustainability success will affect decision-making and drive the achievement of company objectives. Research by (Bank & Murphy, 2013), showed they have tried to explore the field of sustainable warehousing. Their work can be viewed as an early-stage study on the Sustainable Warehouse Management System (SWMS), as they implemented specific SWMS sustainability metrics considering the three social, economic and environmental dimensions of sustainability. While there are several studies on SWMS performance measurement, the number of studies that fully consider the approach while focusing on all warehouse operations is confined and needs to be enriched. The comprehensive and precise indicators to assess the sustainability of SWMS have not

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been developed, and current indicators cannot cover all angles of sustainability.

3. Methodology

3.1 Symptom Versus Problem (SVP)

Symptom Versus Problems (SVP) defines the root problems that are being faced by certain groups and organizations. Derived from the Why-Why analysis concept, SVP are being divided into several columns, referred as tier. There is a total of 6 tiers. Each is related with each other resulting from asking the question 'why' or 'because of what'. Tier 1 will describe about the main issue. For example, issue that proves to be constraints towards achieving the business goals. Then, tier 2 & 3 would be the case issue as it elaborates more on the effects and scenarios that occurs due to the main issue in tier 1. Labelled as the case issue, tier 2 & 3 will be followed by tier 4 to describe the event happening that brings closer to the main problem. Tier 5 will then describe the main problem that need to be tackle in order to achieve the targets. Tiers 4 & 5 are labelled as the case analysis as it resulted in stating the main problems of this issue. Tier 6 will describe the proposed solution that major business need to apply in attempt to solve this issue. The strength of SVP lies in a well structure column that enables the company to observe the root cause of the issues in a structural way. For example, in the case issue problems, the scenarios can sum up to more than one column for the company to foresee. The same function applies to the case analysis in tier 4 & 5. The wide variability and volumes allow the problems observation process to be crystal clear and as a result identification of the problem be much easier. Companies may take this as an opportunity to use this method in adding more case issues in the tier 2 & 3 column so that all unfortunate issues are view and hope to be tackle in striving the company goals.

3.2 Mathematical Computation: Frazelle Model

The Frazelle model is a mathematical approach in this study which is classified into several major warehouse activities which are receiving, put away, storage, order picking and shipping. For the key performance indicators (KPI), items to be calculated based on the activities which is financial, productivity, utilization, quality & cycle time. As example, if the problem resulted from the first part is from the 'productivity' category and about order picking, order lines picked per man hour mathematical formula is applied. With a total of 25 mathematical formula as depicted in Figure 1, majority performance aspect in the warehouse can apply this formula. This study showed the steps in finding the storage utilization rate for the warehouse. The purpose of using this model doesn't limit to calculate storage utilization, but to the extent of increasing warehouse capacity in redesigning the layout of the warehouse. The functionality of this model allows this study to use the formula as the variable in maximizing the usage and capacity of the warehouse in terms of the space area.

There are 3 steps to follow when computing: (1) The first step shows the equation of finding the value of usable warehouse space. In this equation, the data required is the full length and width of the warehouse in order to calculate the area. The area will then subtract the non-storage purpose area for instances, the workstations and forklift and stacker parking area. (2) The usable warehouse space is multiplied with the warehouse space clear height, indicating that the height proves to be crucial in the warehouse storage capacities. (3) Last step shows the warehouse storage capacities is divided with the total volume of product and multiplied by 100 to produce the utilization rate. This method shows, the cruciality in collecting the data of pallet box sizes, warehouse space area and average number of inventories. The data in this study is collected from interviewing several personnel in the warehouse and an officer in the purchasing and logistics department.

$$Uws = Sa - NSPa$$

$$S_A = \sum S_L * \sum S_W$$

$$NSP_A = \sum NSP_L \times \sum NSP_W$$

Were,
U_{WS} = Usable warehouse space
S_A = Size of warehouse area
$\sum S_L$ = Total length of warehouse
$\sum S_W$ = Total width of warehouse

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NSP_A= Non storage purpose area
$\sum NSP_L$ = Total length of non-storage purpose area
$\sum NSP_W$= Total width of non-storage purpose area

Step 2:

$WSc_3 = U_{ws} \times WSC_H$

were,

WSc_3 = Warehouse storage capacities
U_{ws} = Usable warehouse space
WSC_H = Warehouse space clear height

Step 3:
$UZ_{ws} = \left[\frac{\sum p^3}{WSc_3}\right] \times 100 \qquad , \sum p^3 = p_l \times p_w \times p_h$

were,
UZ_{ws} = Utilization rate of warehouse storage
WSc_3 = Warehouse storage capacities
$\sum p^3$ = Total volume of all products
p_l = Length of products
p_w = Width of products
p_h = Height of products

3.3 Discrete Event Simulation (DES)
This study chooses to perform discrete event simulation on the warehouse operations by using Anylogic Simulation software. Discrete event simulation (DES) is a method used to simulate the events of real world (Joel, Louis & Chuan, 2000). In this research, DES can focus on certain activity to provide a detail necessary information needed by the manager. For example, the total throughput and the lead time taken by the pick & pack process can be formulated. Also, the replication of process over time where the real-life movement of the warehouse activities may be observed and visualized without the big usage of company's financial and men power resources. Besides, this software also may calculate the data such as the mean, average & total throughput for the warehouse activity effectiveness based on the item limit and other factors. Based on (Centeno & Carrilo, 2001), there are seven simulation steps. First step is formulating the issues by reformulating the problem to gain better understanding. This is due to the unreliable claimed problem with the real problem that exists. Next, collect the require data and information related to the simulation event and construct a conceptual model. Third step is the verification of conceptual model. Verification is needed to ensure that the process is move in the right direction. Fourth is programming the prototype and run it. Step five is to validate the output of the simulation whether it is reliable or almost equal to the real-world scenario. Afterwards is the experimenting, designing, performing and evaluating on all aspects such as lot sizes, throughput and number of products. In this step, several scenarios will be conducted in which to prove the capabilities of the events under several circumstances and the outcome of it. Lastly, the simulation is present and run on the computer to view the outcomes and end results. This is where, the current and the proposed improved layout is showed so that a clear improvement can be observed clearly.

4. Results
4.1 SVP Analysis
Figure 1 demonstrates a structure detail of the SVP analysis where problems, symptom and solution are depicted from tier 1 to tier 6. It stated that the warehouse space utilization is indeed one of the problems of this company. The solution is then proposed as followed. This figures answers and fulfils the first research question and objectives which to identify the main problem of this warehouse. Using the material handling systems and logic a current warehouse model is projected in Figure 2 followed by mathematical computation of utilization storage using Frazelle

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Model.

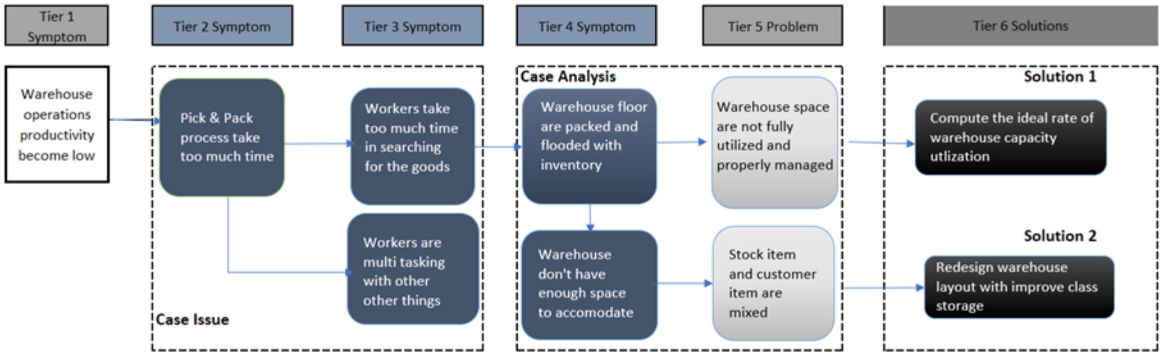

Figure 1. The SVP analysis of the warehouse's problems.

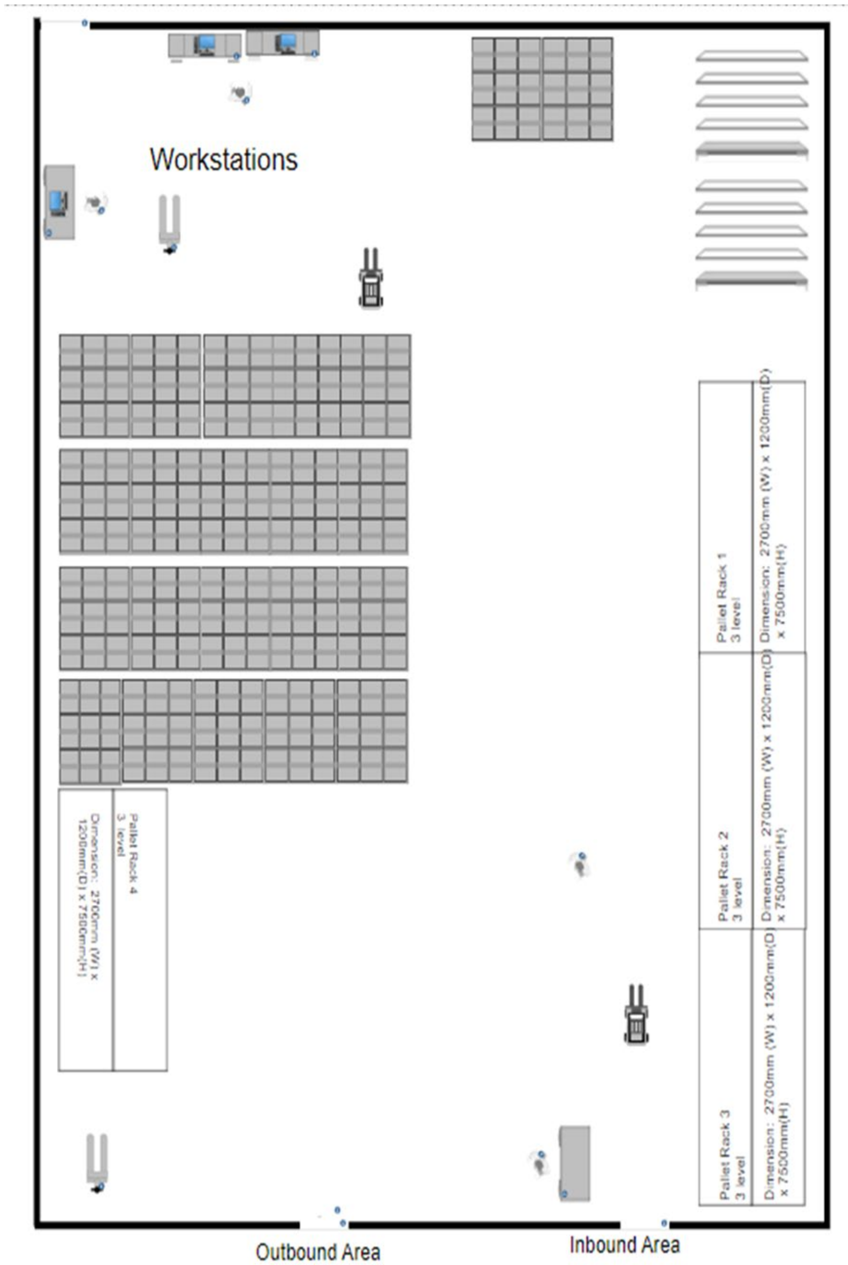

Figure 2. Current State Warehouse Design

4.2 Mathematical Computation of utilization storage using Frazelle Model

Current warehouse mathematical computation
Step 1:

$U_{ws} = S_A - NSP_A$

$S_A = \sum S_L \times \sum S_W$ $\quad\quad\quad$ $NSP_{A=} \sum NSP_L \times \sum NSP_W$

were,

U_{ws} = Usable warehouse space

S_A = Size of warehouse area
NSP_A= Non storage purpose area

$S_A = 13m \times 25m$ $\quad$ $NSP_{A=}$ $15\ m \times 6.25\ m$
$= 325\ m^2$ $\quad$ = 93.875 m2

=325 - 93.8725
U_{ws}= 231.1275 $m2$

Step 2:

$WSc_3 = U_{ws} \times WSC_H$

were,

WSc_3 = Warehouse storage capacities
U_{ws} = Usable warehouse space
WSC_H = Warehouse space clear height

= 231.1275 m^2 × 32 08 m^3
WSc_3= 7396.08 m^3

Step 3:
$UZ_{ws} = \left[\frac{\sum p^3}{WSc_3}\right] \times 100$ $\quad$, $\sum p^3 = p_l \times p_w \times p_h$

were,
UZ_{ws} = Utilization rate of warehouse storage
$\sum p^3$ = Total volume of all products

One large size wooden box dimension (s) = (1150 mm × 750 mm × 1150 mm)
= 0.9918 m^3
0.9918 m^3 × 860 large boxes = 852.948 m^3
One medium size wooden box dimension (s) = (900 mm × 650 mm × 620 mm)
= 0.3627 m^3
0.3627 $m^3 \times 1120$ medium boxes = 406.224 m^3

One small size wooden box dimension (s) = (750 mm × 600 mm × 600 mm)
= 0.252 m^3
0.252 m^3 × 1380 small box = 347.76 m^3
$\sum p^3 = 852.948 + 406.224 + 347.73$ = 1606.932 m^3

$UZ_{ws} = \left[\frac{\sum p^3}{WSc_3}\right] \times 100$
$\left(\frac{1606.932\ m^3}{7396.08\ m^3}\right) \times 100$
= **21.73 %**

According to (Hill, 2007), the maximum storage capacity utilization is 80%. This proof that the current warehouse is far from achieving the optimum value of storage utlization (Figure 3).

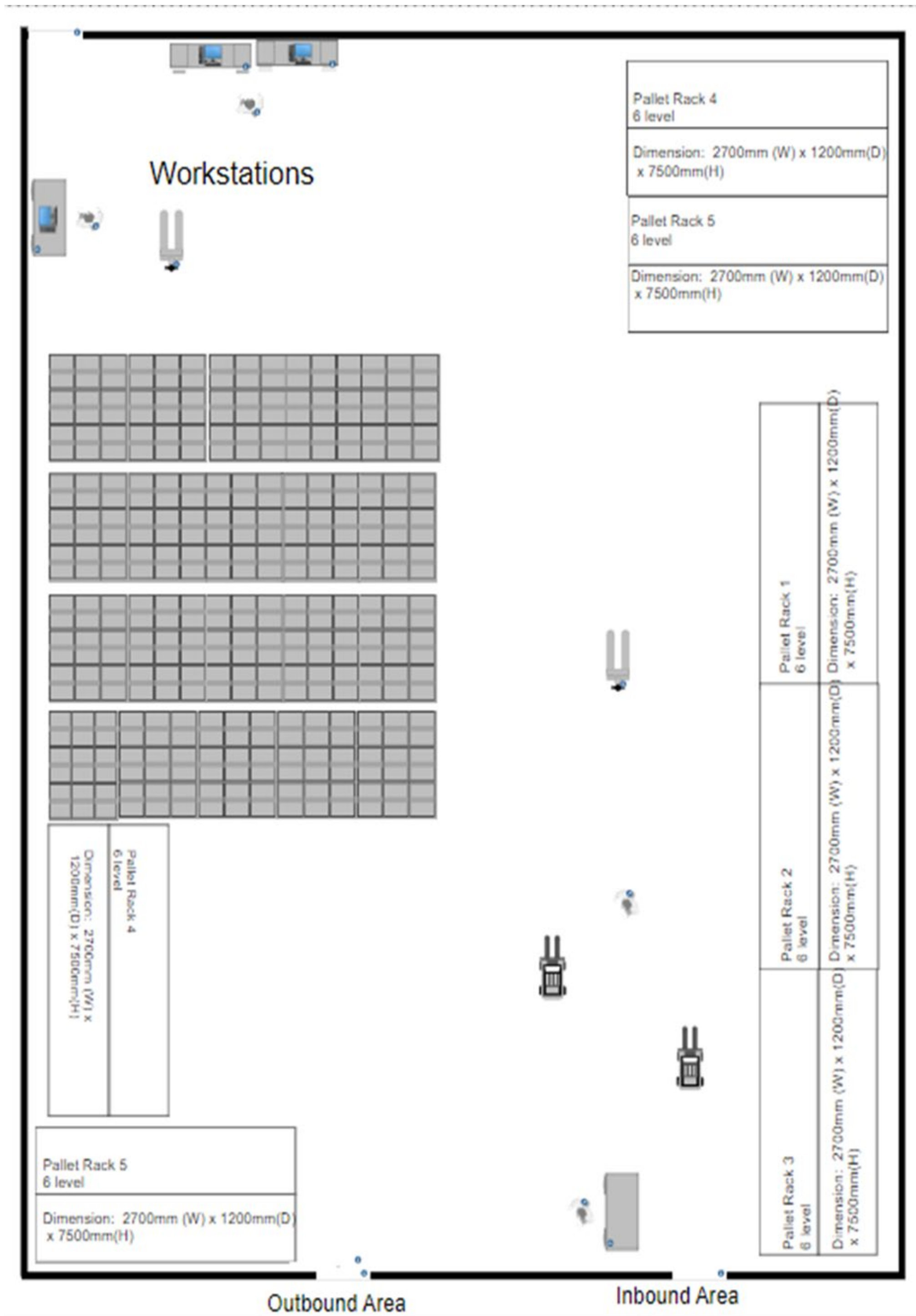

Figure 3. Improved Future State

4.3 Improved warehouse layout mathematical computation

Step 1:

$U_{ws} = S_A - NSP_A$

$S_A = \sum S_L \times \sum S_W$ $NSP_{A=} \sum NSP_L \times \sum NSP_W$

where,

U_{ws} = Usable warehouse space
S_A = Size of warehouse area
NSP_A= Non storage purpose area

$S_A = 13m \times 25m$ $NSP_{A=} 12m \times 4.25\ m$
$= 325\ m^2$ = 51 m2

=325 - 51
$U_{ws} = 274\ m2$

Step 2:

$WSc_3 = U_{ws} \times WSC_H$

where,

WSc_3 = Warehouse storage capacities
U_{ws} = Usable warehouse space
WSC_H = Warehouse space clear height

$= 274\ m^2 \times 32\ m$
$WSc_3 = 8768\ m^3$

Step 3:
$UZ_{ws} = \left[\frac{\sum p^3}{WSc_3}\right] \times 100$, $\sum p^3 = p_l \times p_w \times p_h$
where,
UZ_{ws} = Utilization rate of warehouse storage
$\sum p^3$ = Total volume of all products in the warehouse

$\sum p^3 = 852.948 + 406.224 + 347.73 = 1606.93\ m^3$

Plus the total amount of box at external warehouse = 3500
Box dimension (s) = (1200 mm × 800 mm × 1100 mm)
= 1.056 $m3$ × 3500
= 3696 $m3$
Plus the total amount of box at Container 1 & Container 3 = 800
Box dimension (s) = (1200 mm × 800 mm × 1100 mm)
= 1.056 $m3$ × 800
= 844.8 $m3$

$$\sum p^3 = 1606.93 + 3696 + 844.8$$
$$= 6147.73\ m3$$

$UZ_{ws} = \left[\frac{\sum p^3}{WSc_3}\right] \times 100$

$\left(\frac{6147.73\ m^3}{8768\ m^3}\right) \times 100$

= **70.11 %**

based on the improved layout, storage utilization rate has reached the optimum value of utilization rate and still has 10% left to reach the peak value of 80%. An improved future state model is projected in Figure 3.

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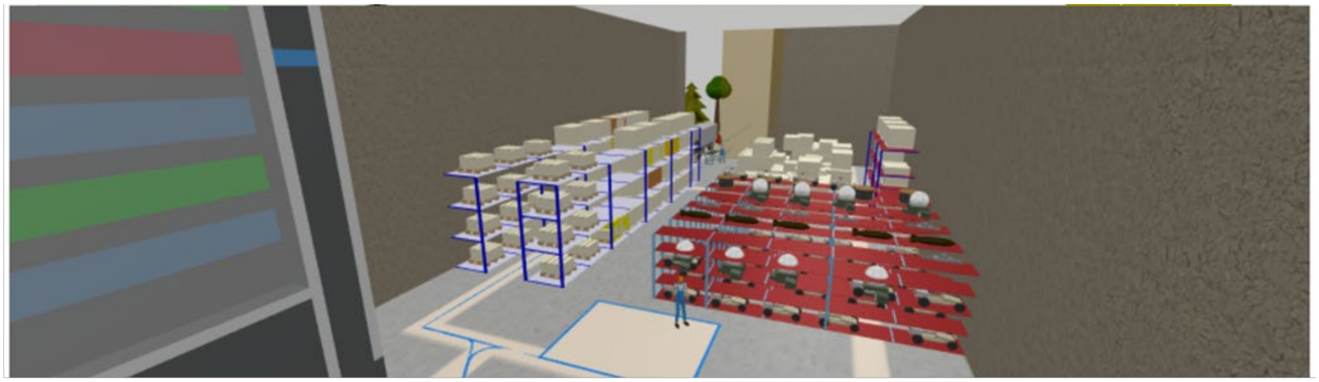

Figure 4. Current Warehouse View (3D)

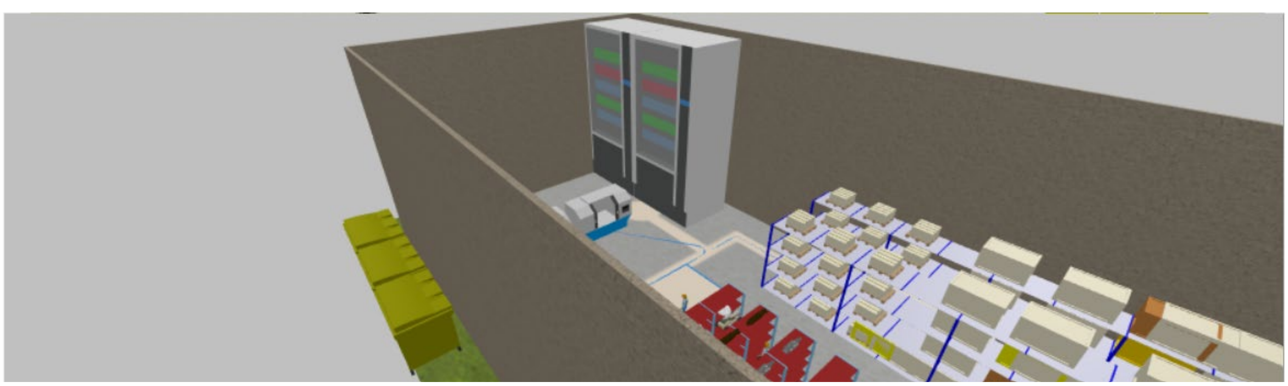

Figure 5. Unused lean lift machines at the corner of the warehouse

Based on Figure 4, it showed that the current warehouse floor has a very packed aisle which caused a very limited movement for the warehouse personnel. As example, when the worker required to look for an item that is underneath the other boxes, it takes longer time to pick that and while moving the other pallet boxes using the forklift. Furthermore, the current warehouse only has pallet racks of 3 level storage which indicates that the upper space is not being utilized properly. Figure 5 shows the inbound area of the warehouse where the forwarder come and left the goods to be pickup by the warehouse personnel. Store personnel usually use forklift to carry the goods as boxes are coming in together with pallet rack. A packed warehouse brings a bad impression towards the company images which shows that the company has poor management in terms of organizing the warehouse inventories. Figure 5 visualized the lean lift machines where according to the warehouse personnel, here were the placed some inventories are being store but due to the physical features of the new products, the lean lift cannot be used any longer.

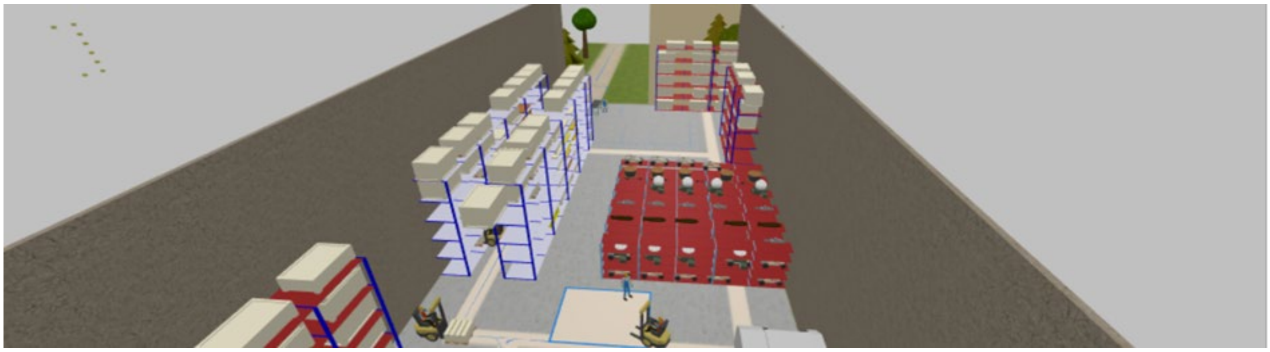

Figure 6. Overall View of Improved Warehouse

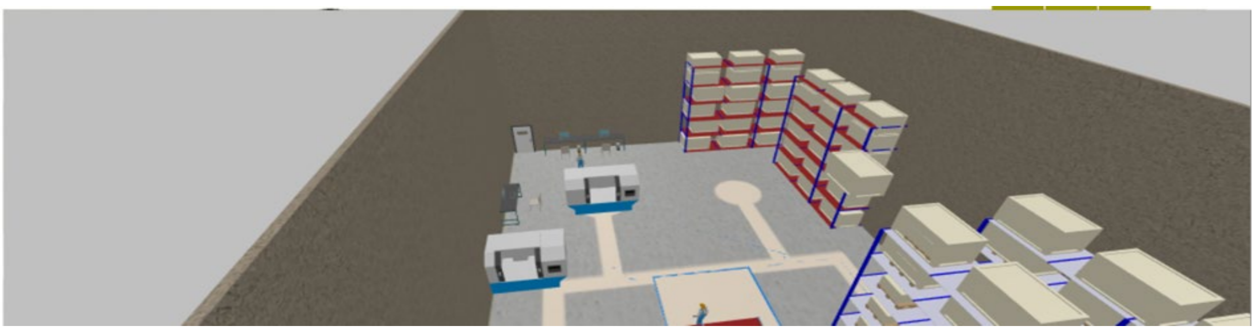

Figure 7. New Pallet and Rack Installed

Figures 6 and 7 depicts the new improved warehouse layout with upgraded level of pallet racks with additional of two more level. A new pallet racks is also installed at outbound are in order to maximize the usage of space in the warehouse for the pallet box to store. Whereas in Figure 5, only two more pallet racks are installed at the place where before, lies the lean lift machines that are not being used anymore. With all the presence and additional pallet racks consist of 6 level storage, this warehouse space utilization rate should increase further.

5. Discussions

5.1 SVP Analysis

The SVP analysis's outcome assisted this study in addressing its first research question, which sought to determine the cause of the poor productivity of the warehouse as it exists now. The investigation indicates that a poor use of space might result in several additional issues. According to Figure 1, selecting slips created for commodities that are positioned far apart will require more time to process. Over 50% of the items must be moved by trolley, stacker, and forklifts due to the weight and size of the products. For instance, packing and shipping ten to twenty distinct goods to a client each day would be necessary for a single selecting slip. A store operator cannot carry all ten goods without moving back and forth from workstations to pallet racks. As a result, when items are lost or positioned widely apart owing to a shortage of space, pick and pack process productivity suffers. The piled floor with pallet boxes in the aisle is another sign highlighted in this study. For example, when an employee of the store must select a product from its bin location, but when checked, it is empty and has yet to be restored, although in the platforms Applications & Products (SAP) platforms it was just received a few days ago. This signifies that the goods are in one of the piled and flooded aisles' pallet boxes. The store's operator cannot carry all ten goods without moving back and forth from workstations to pallet racks. As a result, when items are lost or positioned widely apart owing to a shortage of space, pick and pack process productivity suffers. The piled floor with pallet boxes in the aisle is another sign highlighted in this study. For example, when an employee of the store must select a product from its bin location, but when checked, it is empty and has yet to be restored, although in the platforms Applications & Products (SAP) platforms it was just received a few days ago. This signifies that the goods are in one of the piled and flooded aisles' pallet boxes.

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5.2 Mathematical Interpretation (Current Warehouse)

This study answers the second research question by using a mathematical computation based on the Frazelle model to calculate the current rate of warehouse storage use. According to the preceding results, the current warehouse utilization rate is 21.73%. This validated the present warehouse management's inadequate storage management. Figure 5 depicts the existing configuration, which shows two lean lift machines that take up a lot of area. According to the method, height is a critical aspect in defining spaces, as high-level pallet rack often uses that area. The lean lift takes up 42 m^2. Every unfilled area is viewed as waste. SVP analysis proved that and Furthermore, the existing pallet rack may accommodate up to three level bays, with each level having a height of 4950 mm. This demonstrates that while the warehouse open area height is 32 meters, the pallet rack only takes up 15000 millimeters of height. While there is one thing to keep in mind while moving a really big pallet box up high, this procedure can go forward as long as the forklifts' and the pallet rack bays' weight limits are not exceeded. Receiving and departing shipment activities are similarly impacted by crowded floor aisles, as seen in Figure 5 for both incoming and outbound shipments.

5.3 Future State Warehouse

This research stresses certain elements in the enhanced warehouse plan, which is to produce more space and maximize the area till the maximum clear height. The lean lift machines have been removed, as shown in Figure 7, to make room for two extra pallet rack 5-level bays. This enables the storage of additional pallet boxes in the warehouse's corner, with their height reaching over 30 m. Furthermore, all modern pallet racks have added two more bay levels, bringing the total to five levels of pallet racks. The action is performed to make use of the warehouse's empty top area. In addition, another pallet rack is added beside the pallet rack 4 as there are empty spaces where at the current warehouse, pallet boxes are stacked and placed on the floor. So, to prevent untidiness and longer goods searching time, a new pallet rack is installed there as depicted in Figure 6 and 7. In the calculation part of the improved layout, there's been an addition of pallet boxes from the external warehouse and the outside container. The company aims to reduce cost and old machinery equipment. Starting from the external warehouse, a substantive amount of RM 10,000 per m^2 is needed to pay for the monthly rental. With a total of 3500 boxes, there are at least half millions can be saved on the financial part to invest on other important area. on the other side, storage outside the warehouse building is much safer compared to inside the container. Also, the lead time taken in bringing the goods from the container to inside part of the warehouse can be eliminate fully. To sum up, all the goods from the external warehouse and the containers are included to calculate whether the new layout capable of holding that much amount of inventory. Finally, the calculated value is 70.11 % where it is an optimum value, considering 80% is the peak value of storage utilization. If the value is too high, it means the warehouse had a prepare a non-conducive workplace where, the movement of the forklift and store worker may be restricted. Too low value of utilization effects means the warehouse does not use the storage effectively and the result is presented in the SVP analysis. In short, the improved warehouse layout is proven to have a higher utilization rate to increase the warehouse productivity.

5.4 Sustainable Warehouse Operations

This study also answers the third research question which, on how the proposed model could improve sustainable warehouse. This company does possess ISO 14000 at bay but apparently the warehouse did not practice sustainability that much. Currently the warehouse uses electric forklifts rather than diesel forklifts. Diesel forklifts require chemicals substances to enable the forklift to operate which leads to water and air pollution. Electric forklifts however use electrical power to operate it. The next feature is a LED based lighting. A LED based lighting is considered as sustainable as it last much longer than the normal penda flour lighting. LED lighting also saved more energy which leads to fewer electric charges and lower impact towards the environment. Basically, this feature allows the company to save more in terms of the cost, maintenances and provide less harm towards environment.

Other features that this study wants to propose to propose a sustainable warehouse model are as follows. The first feature is the proper insulation of warehouse building. A poor insulated building makes the cool air to escape the building which resulted in temperature increase inside the warehouse. A hot working environment is considered as poor ergonomic towards the worker which may lead to exhaustion and the usage of air conditioner which release material Chlorofluorocarbon gas and cause greenhouse effect. There are several materials contribute to sustainable warehouse. (1) Cellulose insulation. 80% of cellulose insulation is made up of recycle material and environmentally friendly. Very suitable for any commercial warehouse and buildings. (2) Next is the fiberglass insulation which is effective in providing heat insulation. Fiberglass is more suited to install at the roof deck to achieve better insulation. Lastly (3) is the radiant barrier insulation. Radiant barrier offers great reflection to the radiant coming from the sun. Radiant barrier offers a great reflection to the radiant heat coming from the sun. It helps to keep the warehouse cool as it does not absorb the heat but reflect it back to space. Installing on the warehouse roof, radiant barriers are very useful if you utilize the warehouse for storing things that require low temperature. It consists of reflective material like foil.

Regarding the natural cooling of the temperature, the use of High-Volume Low Speed (HVLS) fans aids in the sustainability aspect since the size of the fans and their blades allows for the use of low speed to adequately reduce the warehouse temperature. The large blades justify the 'High Volume' element, which allows it to cover a wide range of warehouse spaces. Low speed means lower electricity costs and less energy released, which saves the environment. The drainage converter system helps the environment by promoting reduced water use in the building on a daily basis. Mainly channel towards the toilet and tap water tank, the water consumed every day is only specialized in drinking. This will cut cost of water bills charge on the company.

5.5 Conclusions

Managing warehouse efficiency while adhering to the sustainability element has emerged as a prominent problem in today's logistics industry. There are several objectives and KPIs to meet while dealing with the continuous business problems of today's trends. Previous research has primarily focused on the broad KPIs of warehouse productivity and the foundations of warehouse storage. Future research should concentrate on other KPIs, such as order picking productivity and cycle time, to quantify performance and strive for top performance in warehouse activities. Previous studies on sustainable warehouses focused on the broad elements and advantages of sustainability but did not identify the specific measures that other parties may take to adopt it, despite the continued problem of logistic businesses being unaware of sustainable warehouses. Given that this study has focused on the environmental and economic dimensions of sustainability, further research on the social dimension of sustainability in warehouse operations has to be prioritized. The contributions of this study includes the improved warehouse layout for the company that acts as a reference for other companies as well. The utilization rate has been calculated on both layouts to describe the ground reality of the warehouse challenges faced. The discrete even simulation teachnique has been adopted to capture the discrete events of the warehouse to capture complex activities. A display of present and future state digital twin of the warehouse has been projected in this study better decision making.

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